X-ray Survey System for Barrel TRT modules

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Abstract

This describes a proposed X-ray survey system (XRSS) for gain and wire-position surveys on completed barrel TRT modules. The chosen X-ray tube will operate up to 80 kV and 60W; it has a spot size of 0.01-0.05 mm, and the beam will be collimated to approximately 0.05 mm wide and 10 mm long. The beam can be positioned within an area 1500 mm (*Z*) by 300 mm (*X*); the *X*-coordinate positioning will have a resolution of 0.01 mm or better. The front-end electronics for the module will be based on the GasSiplex chip, one chip per stamp board, operated in 'transparent mode.' The analog output from any chip will be steered to one of four multi-channel analyzers, giving a maximum acquisition rate of 400 kHz. The XRSS will be controlled by a Windows NT and BridgeView system

1 Introduction

The ATLAS TRT barrel modules are to be surveyed for gain and wire position at Hampton University before being shipped to CERN. It is desired to survey every straw and sense wire. Gain measurements should be done at a minimum of 14 points along the straw and wire position measured at four places, two coordinates at each place. It must be possible to complete the survey in five working days, including mounting the module, mounting the electronics, flushing with gas, ramping up the HV, and analyzing the data. The nominal schedule for production is approximately two modules every 17 days; there are other tests that need to be done.

Prototype X-ray systems have been used at PNPI and Duke University, with somewhat different characteristics. We propose to follow the Duke approach, using a tungsten-anode X-ray tube giving a continuous X-ray spectrum and comparing energy-deposit spectrum shapes to find relative gain and wire position. Some work may be done with an ^{55}Fe source to give an absolute calibration, but not the overall survey.

2 System requirements

2.1 Gain measurement

The requirements for gain measurement are as follows:

- Measure relative gain along each wire to 2% (combination of statistical and systematic uncertainties) at a minimum of 14 places along the 1500-mm length. (A continuous map at a resolution of 10 mm is also possible.)
- Capture continuous record of gas mixture, flow rates, ambient temperature, pressure, HV applied, X-ray parameters, etc.
- Complete the survey of a type-3 module in one working day, in an unattended mode.

2.2 Position measurement

The requirement for position measurement is:

- Measure position of each wire in two coordinates (*X* and *Y*) to a circular uncertainty of 0.05 mm at four places (the ends and each side of the center twister). The range in *Z* for each measurement will be up to 50 mm; its center will be known to 1 mm or better.
- The coordinate system is to be established by the support-pin holes in the module end.

2.3 Control system

Requirements on the control system are:

- Resolution of *X* position control of beam to be 0.01 mm or better
- Resolution of *Z* position control to be 1 mm or better
- System may be open-loop provided precise limit and home positions are available
- Control or indicate and alarm parameters such as HV, X-ray settings, and gas flow.

2.4 Mechanical system

The requirements on the mechanical system are:

- X range of 300 mm; maximum speed necessary is 10 mm/s
- Z range of 1500 mm; maximum speed necessary is 50 mm/s
- Module rotation capability (300° min); maximum speed is 3°/s
- Positioning of X-ray tube in *X* with resolution of 0.01 mm and repeatability of 0.02 mm
- Linearity of position of beam over full depth (*Y*) of module (range of about 300 mm) of better than 0.025 mm over *X* range (also 300 mm)
- Positioning and repeatability in *Z* to 1 mm.
- Stability within normal temperature range (65 – 75° F).

2.5 X-ray system

The requirements for the X-ray system are:

- HV up to 80 kV
- Small spot (<0.05 mm) to permit well-defined beam.

The chosen tube has a power rating of 60W and a maximum current rating of 2.5 mA.

2.6 Data acquisition system

The data acquisition system must be capable of acquiring spectra at a rate that allows analysis to meet the precision goals above, and to complete the surveys on schedule. The spectrum will vary with depth, so only relative gain measurements can be made along the straw. Some improvement can come from rotating the beam around the module (4 directions) so that the maximum depth for data collection is half the module. Also we have to be sure that variations of density, of the material in the beam, along the straw is not interpreted as a gain variation.

The basic technique is to scan with an X-ray beam using ‘transparent’ Gassiplex readout. The advantage is intensity and high energy (compared with ^{55}Fe) for better penetration. A disadvantage is that the spectrum is not monochromatic (without a lot of effort) and may soften as it penetrates. Experience at Duke has been good, with variation in rate from 10 kHz (raw) to 1 kHz (12 layers deep in module).

2.6.1 Gain measurement

As noted above, the minimum is to measure in 14 places: at each divider (5 places) , at HV plates (+2), both sides of center divider (+1), and between dividers (+6). This is the minimum set, assuming that gain variations are due to the straw being off-center relative to the wire, and that the straw has a simple bend between dividers. For a type-3 module that gives a total of 14 x 4 x 400 places say, or 20,000 spectra. If we can collect two spectra at a time, that means 10,000 samples. The result is the relative gain at 14 places for each straw; the resolution in the *Z* direction could be 1 mm.

An alternative is to measure with overlapping spots along straw and cover entire straw. For a 10 mm spot that would mean 150 places. This is a better option, since there may be problems not due to lack of concentricity. Also radiator density variations may cause apparent gain variations; the wider spot will average these out. This gives a total of 150 x 800 spectra, or 120,000. If we do two at a time, 60,000 samples at one per second gives a running time of 17 h.

2.6.2 Wire position measurement

We will measure in 4 places: at the HV plates and both sides of the center divider, relative to a line between the mounting pins. An intelligent scan would scan a range of about 0.4 mm for each wire, with a step of 0.01 mm. For a type-3 module, there would be 40 x 800 x 2 (X,Y) spectra at a minimum. Scanning in different orientations would double this, for a total of 128,000. Taking two spectra at a time would give 64,000 , some at rates as low as 1 kHz. Although Duke has made measurements of wire position with 1-second samples with the low rate, the precision of peak location is lower. The running time for a complete survey is about 18 hours.

2.6.3 The GasSiplex chip

The designated readout chip for TRT testing purposes is the GasSiplex chip. It is a 16-channel, sample-and-hold, sequential read-out, amplifier custom chip. It is a 44-terminal SMD. For our purposes, it will be operated in the ‘transparent’ mode. One of the 16 channels will be selected, and inputs on that channel will be amplified and passed to the output. The channel is selected by applying a CLR pulse, then a string of CLK pulses corresponding to the channel. Each chip then needs a cable that carries +&-3.5V (or +&-5V), CLR, CLK, test, and the analog output.

We will need to have 100 chips installed (1600 signals) and be able to readout at least 50 at any time (50 chips on each end of a type-3 module, there is a wire joint in the center so only one end is active in a survey, with one X-ray source).

A notable feature is that, typically, each chip is connected to a 4x4 group of straws. Thus only one straw can be read out at a time in each group, complicating any readout sequence strategy.

2.6.4 Control and DAQ requirements

Note that, for X-ray testing there is no correlation between channels, so that the standard HEP/NP electronics is a bad match to the signal character. A typical, or even fast, readout system can do many channels at rates up to 4 kHz for correlated events. In the X-ray (or ^{55}Fe) survey, only one straw fires at a time (the X-ray beam is DC, not pulsed), so the data would be very sparse – one data word per readout cycle. Histogramming is done in the DAQ CPU. (Rates can be improved by using selected ADC units with buffers, but the cost is high and there are dead-time issues.)

On the other hand, a multi-channel analyzer can run at up to 100 kHz, and forms the histogram in hardware. To collect data from more than one straw at a time we do need multiple ADC channels and a flexible selection mechanism to:

- select the active chips
- select the active channel in each chip
- select the ADC to which the signals are directed.

On average, three wires will be in a single X-ray beam at any one time, so 4 ADCs seems a reasonable choice. (By using two beams, we may be able to keep 4 ADCs busy, for a peak rate capability of 400 kHz.) That means a 64-to-4 cross-point switch is needed, along with the ability to program each GasSiplex chip.

We also want to collect data from a small calibration chamber that measures the gain characteristics of the active gas; its output would be part of the system.

2.7 Software

The software selected by the TRT collaboration is BridgeView, and we have chosen Windows NT. Data analysis software is not determined, but will likely be a version of paw or ROOT.

3 Description of system

A general schematic of the system is shown in figure 1. Control and DAQ is done via a PC running BridgeView; PCI interface.

3.1 Mechanics

Use stepper motors and linear motions.

3.2 Electronics

There are various options. One option is the GPX board and CXS module approach, both non-commercial elements. The GPX front-end board is based on the GasSiplex chip, and the CXS is a control and cross-point switch. These have to be built. A block diagram of the CXS is shown in figure 2; it will use the Analog Devices AD8110 16x8 switch, figure 3.)

Data will be collected by a multi-channel analyzer system with four ADCs.

4 Data formats

Depending on option, there may be up to 120,000 measurements, for one module type 3, with 4 parameters (Straw number, z-position, gain, resolution). It could also be in the form of (329, 520, 793) histograms. There would be some supporting data, like temperature, gas mix, HV that would go along with the data.

Result would be up to 16 x,y,z triplets (for each wire plus specifications of at least one coordinate system, times 800 for module type 3.

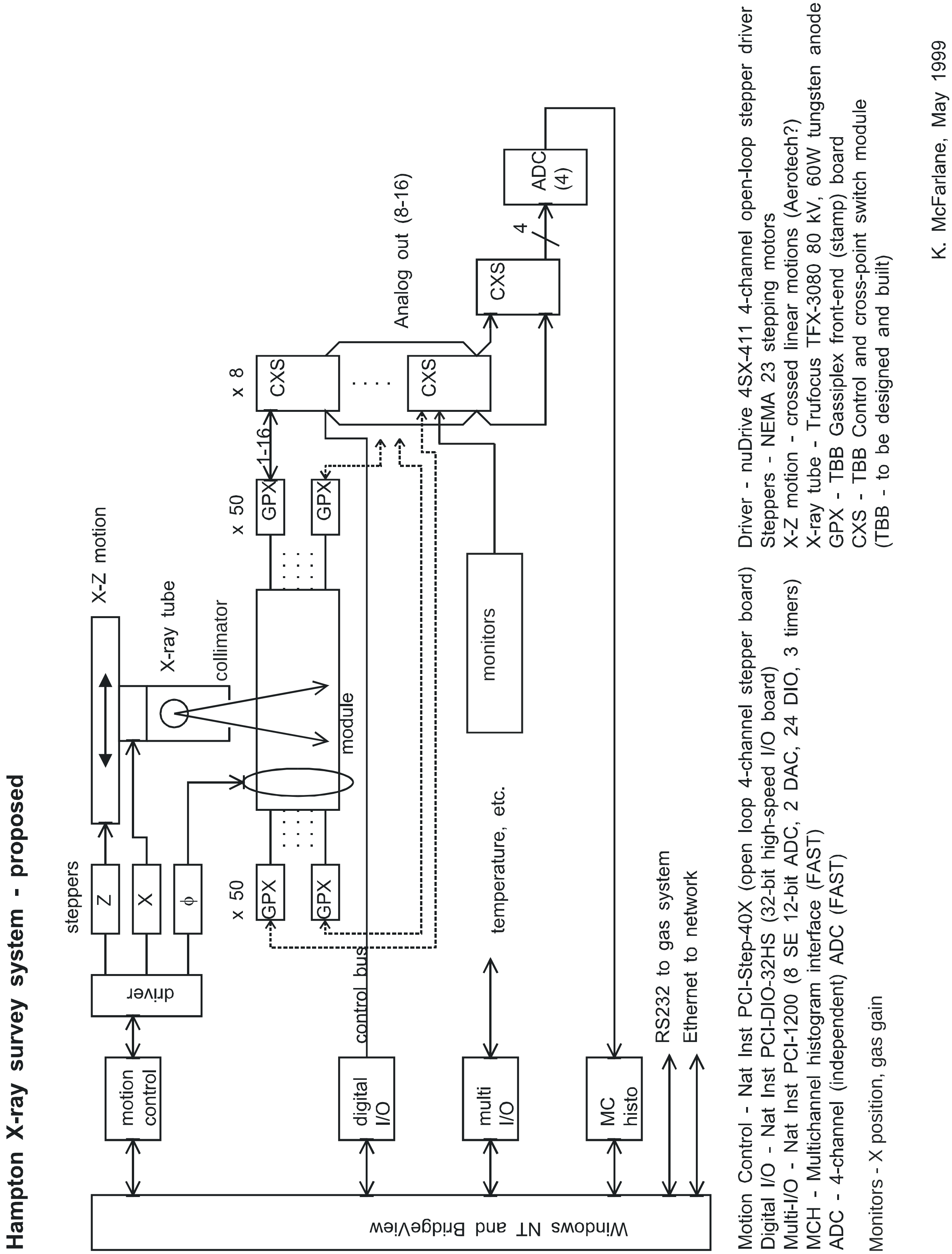

Figure 1 – Schematic of X-ray survey system

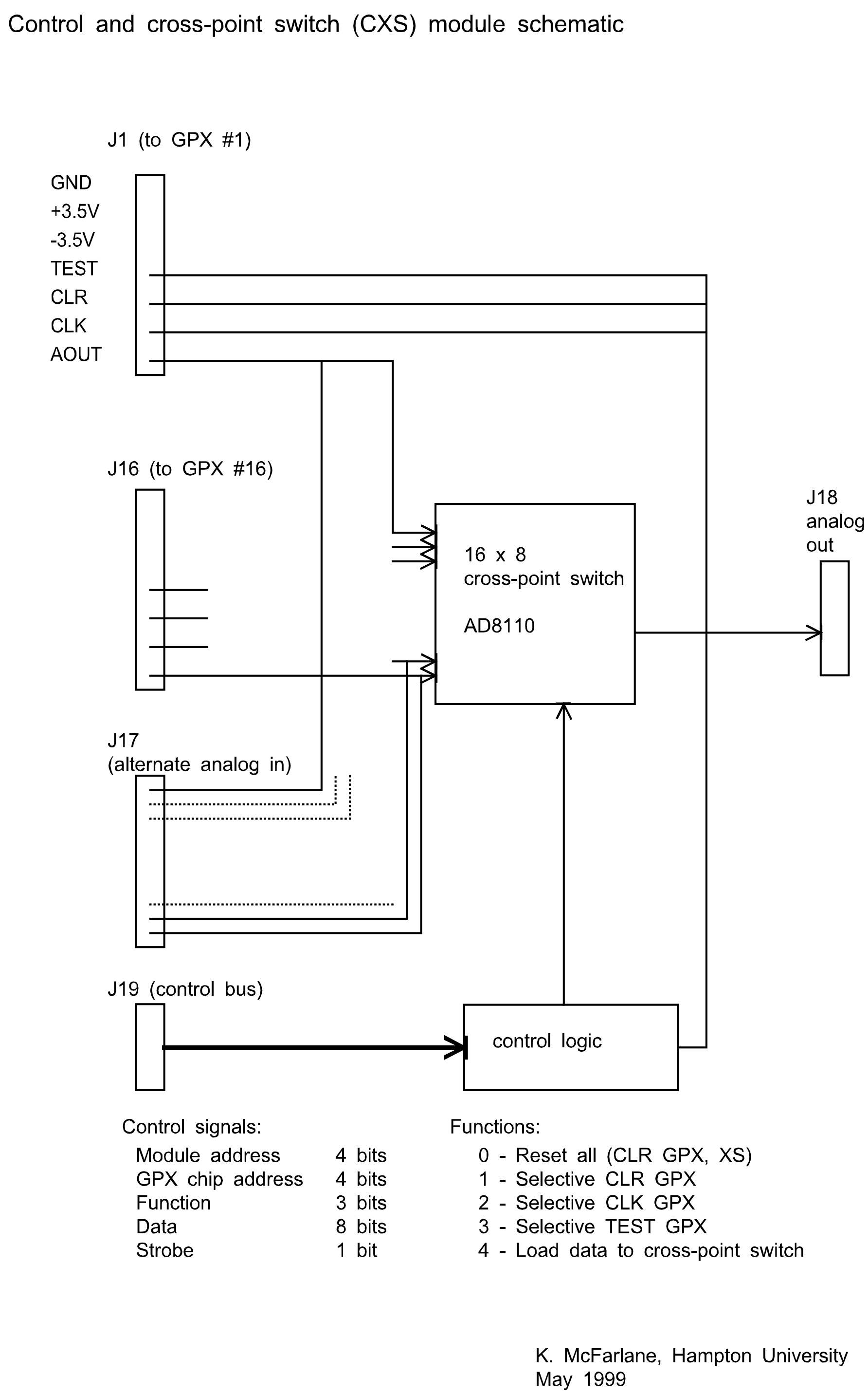

Figure 2 – Schematic of Control and cross-point switch (CXS) module.

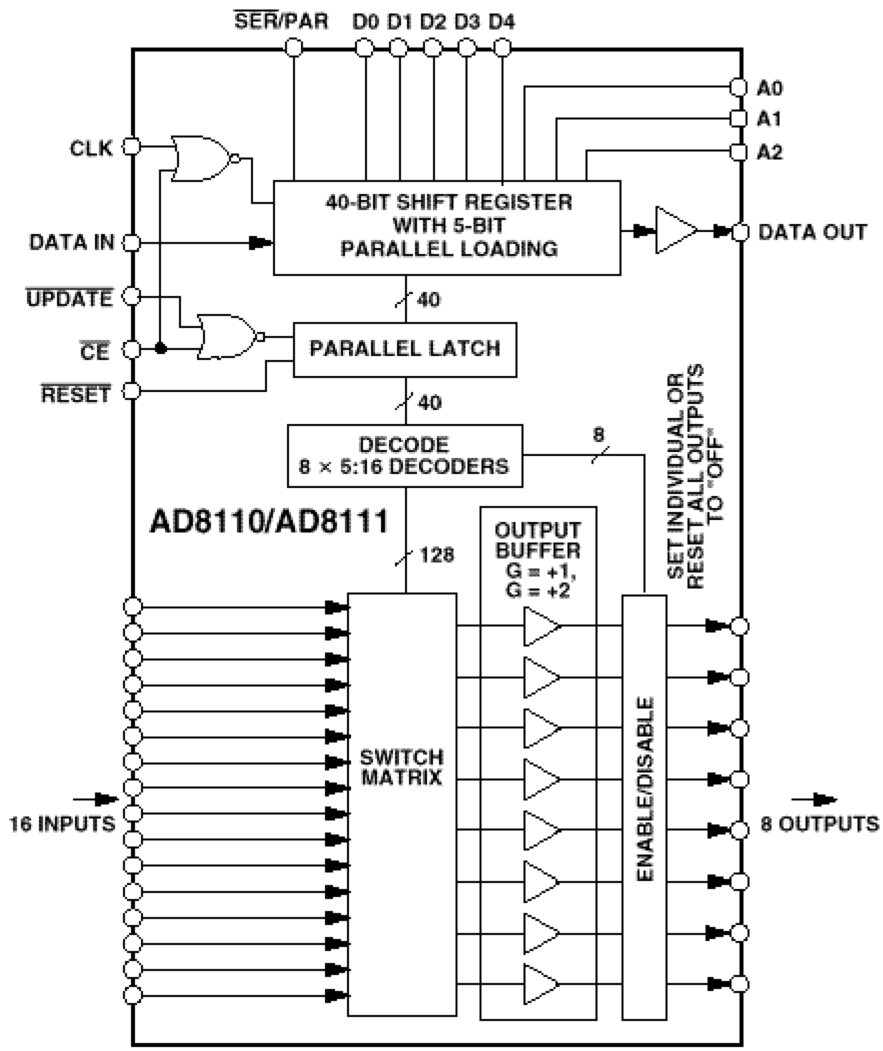

Figure 3 – Analog Devices AD8110 16 x 8 video crosspoint switch.